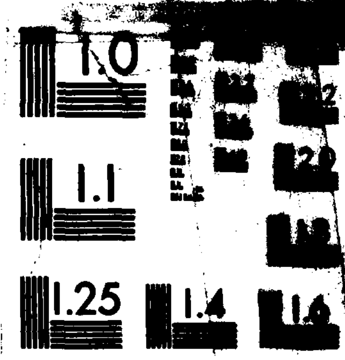
AD-A158 219 ERRORS DUE TO COUNTING STATISTICS IN THE TRIAXIAL STRAIN (STRESS) TENSOR..(U) NORTHWESTERN UNIV EVANSTON IL DEPT OF MATERIALS SCIENCE P RUDNIK ET AL. 01 JUL 85 1/1

UNCLASSIFIED TR-18 N00014-80-C-0116 F/G 20/11 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1

NORTHWESTERN UNIVERSITY

DEPARTMENT OF MATERIALS SCIENCE

TECHNICAL REPORT # 18
July 1985

OFFICE OF NAVAL RESEARCH
CONTRACT # N00014-80-C-116
Ø

ERRORS DUE TO COUNTING STATISTICS IN THE TRIAXIAL STRAIN (STRESS) TENSOR DETERMINED BY DIFFRACTION

BY

P. Rudnik and J. B. Cohen

NORTHWESTERN UNIVERSITY · QUAECUMQUE SUNT VERA · 1851

EVANSTON, ILLINOIS

1

ERRORS DUE TO COUNTING STATISTICS IN THE TRIAXIAL STRAIN (STRESS) TENSOR DETERMINED BY DIFFRACTION

P. Rudnik and J. B. Cohen

Department of Materials Science and Engineering
The Technological Institute
Northwestern University
Evanston, IL 60201

INTRODUCTION

Knowledge of the errors in a diffraction measurement of residual strains and stresses is useful information, not only in its own right, but also because it permits automation of a measurement to an operator specified precision.[1] There are three sources of these errors:

(1) Instrumental effects, primarily due to sample displacement, separation of the θ and 2θ axes of the diffractometer, and beam divergence. All three can be estimated[2], or minimized by employing parallel beam geometry.[3]

(2) Uncertainties in x-ray elastic constants, which can now be evaluated.[4]

(to p173)

and (3) Errors in the diffraction peak position related to counting statistics. Equations to evaluate this source have been developed in Ref. 1 for the case of a stress state for which all σ_{i3} (i = 1,2,3) = 0, with the direction "3" normal to the sample surface, see Fig. 1. This means that the stresses lie only in the surface, e.g., a biaxial stress state $\begin{vmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{12} & \sigma_{22} \end{vmatrix}$. There are, however, numerous situations when the normal components are appreciable in an x-ray measurement[5,6] and this is generally the case for neutron diffraction because with neutrons the beam can sample a sizeable volume, at a significant depth below the surface[7]. It

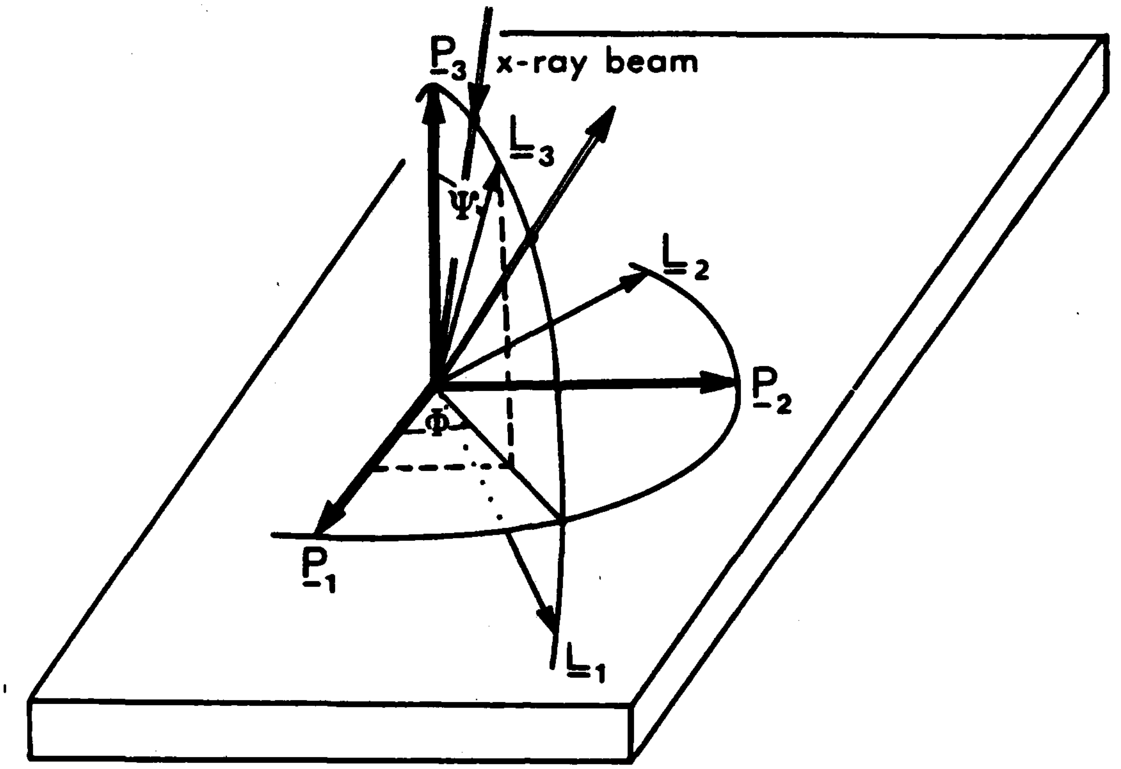


FIG. 1: The axial system. Strains are measured with diffraction by measuring the change in spacing of planes normal to the L_3 direction. (The axes P_i define the specimen surface.)

TABLE I: STRESS TENSORS (AND STANDARD DEVIATIONS) FOR SPECIMEN C3, REF. 5

		DATA SET 1			
537.62	(161.94)	-24.03	(78.81)	-39.15	(4.58)
		550.04	(161.66)	2.31	(3.56)
				78.29	(130.57)
		DATA SET 2			
520.60	(137.25)	-4.03	(66.60)	-34.17	(3.21)
		555.19	(137.03)	0.11	(2.69)
				82.20	(110.67)
		DATA SET 3			
535.03	(158.28)	-20.13	(77.06)	-40.19	(5.72)
		555.98	(157.99)	-0.98	(4.56)
				86.66	(127.69)
		DATA SET 4			
538.53	(146.23)	-30.63	(70.95)	-38.03	(3.83)
		565.37	(146.14)	0.76	(3.89)
				88.18	(117.92)

AVERAGE			REFERENCE 5		
532.95	-19.69	-37.89	541	-20	-38
	556.65	0.55		565	1
		83.83			86

* values given in MPa; $V(d_0)^{\frac{1}{2}} = 0.00016$ Å

is the purpose of this paper to derive equations to evaluate the counting statistical error for the entire three dimensional strain (or stress) tensor,
$$\begin{vmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{vmatrix}.$$

BASIC EQUATIONS

We begin with the general equation for the strains (ε_{ij}) and how these affect the interplanar spacing "d". (Refer to Fig. 1 for the axial system.) The measurement is made in the Φ direction, with a sample tilted ϕ from the normal position (which is with the surface normal bisecting incident and scattered beams). Primed quantities refer to strains in the L_i co-ordinate system, unprimed terms are in the P_i system.

$$\langle\varepsilon'_{33}\rangle_{\Phi\phi} = (d_{\Phi\phi} - d_0)/d_0 = [\langle\varepsilon_{11}\rangle \cos^2\Phi + \langle\varepsilon_{22}\rangle \sin^2\Phi + \langle\varepsilon_{12}\rangle \sin 2\Phi$$
$$-\langle\varepsilon_{33}\rangle] \sin^2\phi + \langle\varepsilon_{33}\rangle + [\langle\varepsilon_{13}\rangle \cos\Phi + \langle\varepsilon_{23}\rangle \sin\Phi]\sin 2\phi \qquad (1)$$

Note that the stress-free spacing, d_0, is involved. While this term can be eliminated for a biaxial stress state, this is not possible for a general strain or stress tensor, and the reader may consult Ref. 8 for a discussion of problems associated with the measurement of this quantity. When ε_{23} or $\varepsilon_{13} \neq 0$, ε'_{33} is not linear with $\sin^2\phi$ and has different curvature for $+\phi$ and $-\phi$. The carats imply that the strain values are averaged over the depth of penetration of the incident x-ray (neutron) beam and this is to be understood in what follows, as this additional notation is eliminated below.

Next, we define terms which involve measurements of $d_{\Phi,\phi}$ at plus and minus ϕ tilts of the surface normal.[5]

$$a_1 \equiv 1/2[\varepsilon'_{\Phi\phi+} + \varepsilon'_{\Phi\phi-}] = \{d_{\Phi\phi+} + d_{\Phi\phi-})/2d_0\}-1$$
$$= \varepsilon_{33} + [\varepsilon_{11} \cos^2\Phi + \varepsilon_{22} \sin^2\Phi + \varepsilon_{12} \sin 2\Phi - \varepsilon_{33}])\sin^2\phi \qquad (2a)$$

Clearly, a_1, should be linear with $\sin^2\phi$ and ε_{33} is the intercept, regardless of Φ.

$$a_2 \equiv 1/2[\varepsilon_{\Phi\phi+} - \varepsilon_{\Phi\phi-}] = (d_{\Phi\phi+} - d_{\Phi,\phi-})/2d_0$$
$$= [\varepsilon_{13} \cos\Phi + \varepsilon_{23} \sin\Phi]\sin|2\phi|. \qquad (2b)$$

Therefore, a_2 is linear vs. $\sin|2\psi|$.

Let:

$$\ell_1 = da_1/d\sin^2\psi, \tag{3a}$$

$$\ell_2 = da_2/d\sin|2\psi| \tag{3b}$$

Then, at: $\phi = 0°$, ${}_0\ell_1 = \varepsilon_{11} - \varepsilon_{33}$,

$\phi = 90°$, ${}_{90}\ell_1 = \varepsilon_{22} - \varepsilon_{33}$,

$\phi = 45°$, ${}_{45}\ell_1 = 1/2(\varepsilon_{11} + \varepsilon_{22}) + \varepsilon_{12} - \varepsilon_{33}$,

$$= \varepsilon_{12} + 1/2({}_0\ell_1 + {}_{90}\ell_1). \tag{3c}$$

and similarly:

at $\phi = 0°$: ${}_0\ell_2 = \varepsilon_{13}$,

at $\phi = 90°$: ${}_{90}\ell_2 = \varepsilon_{23}$. (3d)

Knowledge of the strain tensor permits the calculation of the stress components (σ_{ij}) from:

$$\sigma_{ij} = [1/2S_2(hk\ell)]^{-1}\{\varepsilon_{ij} - \delta_{ij}\{S_1(hk\ell)/[3S_1(hk\ell) + 1/2S_2(hk\ell)]\}\cdot[\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}]\}. \tag{4}$$

Here, δ_{ij} is the Kronecker delta function and S_1 and $1/2S_2$ are the x-ray elastic constants which depend on the indices of the diffraction peak, $hk\ell$. (For an isotropic solid these values are $-\nu/E$ and $(1 + \nu)/E$ respectively.)

VARIANCES DUE TO COUNTING STATISTICS

For a function $X = f(x_1, x_2, x_3 \ldots)$, assuming the x_n are independent, the variance (V) is[9]:

$$V(X) = \left(\frac{dX}{dx_1}\right)^2 V(x_1) + \left(\frac{dX}{dx_2}\right)^2 V(x_2) + \left(\frac{dX}{dx_3}\right)^2 V(x_3) + \ldots \tag{5}$$

For the straight line, $y = mx + b$, the slope and intercept is given by:

$$m = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sum_i (x_i - \bar{x})^2} \tag{6a}$$

$$b = (\Sigma y_i - m\Sigma x_i)/N \tag{6b}$$

where N is the number of data points.

Employing Eq. (5):

$$V(m) = \left[\frac{\sum_i (y_i - \bar{y})}{\sum_i (x_i - \bar{x})^2}\right]^2 V(x) + \left[\frac{\sum_i (x_i - \bar{x})}{\sum_i (x_i - \bar{x})^2}\right]^2 V(y) \tag{6c}$$

Therefore:

$$V(b) = \frac{\Sigma(x_i - \bar{x})^2}{N} \cdot V(m) = \frac{\Sigma(x_i - \bar{x})^2}{N} \cdot \left\{ \left[\frac{\Sigma(y_i - \bar{y})}{\Sigma(x_i - \bar{x})^2}\right]^2 V(x) + \left[\frac{\sum_i (x_i - \bar{x})}{\Sigma(x_i - \bar{x})^2}\right]^2 V(y)\right\} \tag{6d}$$

Therefore; in terms of a_1 vs. $\sin^2\phi$:

$$V(\ell_1) = \left[\frac{\sum_i (a_{1i} - \bar{a}_1)}{\sum_i (\sin^2\phi_i - \overline{\sin^2\phi})^2}\right]^2 V(\sin^2\phi) + \left[\frac{\sum_i(\sin^2\phi_i - \overline{\sin^2\phi})}{\sum_i(\sin^2\phi_i - \overline{\sin^2\phi})^2}\right]^2 V(a_1) \tag{7}$$

The variance in ϕ is negligible, so the first term can be ignored.

Also, from Eq. (2a):

$$V(a_1) = \left[\frac{da_1}{d(d_{\phi\psi+})}\right]^2 V(d_{\phi\psi+}) + \left[\frac{da_1}{d(d_{\phi\psi-})}\right]^2 V(d_{\phi\psi-}) + \left[\frac{da_1}{d(d_0)}\right]^2 V(d_0) \tag{8}$$

Writing Bragg's law in the form $d = \frac{\lambda}{2\sin\theta}$, adopting the convention that θ^+, θ^- are the θ values (in degrees) for the peaks at $+\psi$, $-\psi$ respectively, and employing Eq. (5):

$$V(d_{\phi,\psi+}) = (\pi/180)^2 (\lambda\cos\theta^+/2\sin^2\theta^+)^2 \; V(2\theta^+)/2 \tag{9}$$

and similarly for $V(d_{\phi,\psi-})$. Recalling Eq. (2a):

$$\left[\frac{da_1}{d(d_{\phi\psi+})}\right]^2 = \left[\frac{da_1}{d(d_{\phi\psi-})}\right]^2 = \frac{1}{4d_0^2}, \tag{10a}$$

$$-\frac{da_1}{d(d_0)} = \frac{[d_{\Phi\psi+} + d_{\Phi\psi-}]^2}{4d_0^4} = d_+^2/4d_0^4. \tag{10b}$$

Thus, we may rewrite Eq. (7):

$$V(\ell_1) = \left[\frac{\sum_i(\sin^2\phi_i - \overline{\sin^2\phi})}{\sum_i(\sin^2\phi_i - \overline{\sin^2\phi})^2}\right]^2 \frac{1}{4d_0^2}\{(\pi/180)^2\ \frac{\lambda^2}{8}\ [(\frac{\cos\theta^2}{\sin^2\theta^+})^2 V_i(2\theta^+)$$

$$+ (\frac{\cos\theta^-}{\sin^2\theta^-})^2\ V_i(2\theta^-)] + (d_+^2/d_0^2)V(d_0)\} \tag{11}$$

In a similar manner for a_2 vs. $\sin|2\psi|$, where $a_2 \equiv (d_{\Phi\psi-} - d_{\Phi\psi-})/2d_0 = {}^{d-}/2d_0$:

$$V(\ell_2) = \left[\frac{\sum_i \sin|2\phi_i| - \overline{\sin|2\phi|})}{\sum_i(\sin|2\phi_i| - \sin|2\phi|)^2}\right]^2 \frac{1}{4d_0^2}\{(\frac{\pi}{180})^2(\frac{\lambda^2}{8})[(\frac{\cos\theta^+}{\sin^2\theta^+})^2 V_i(2\theta^+)$$

$$+ (\frac{\cos\theta^-}{\sin^2\theta^-})^2\ V_i(2\theta^-)] + (d_-^2/d_0^2)\ V(d_0)\} \tag{12}$$

We now propagate these values into the strain and stress tensors.

THE STRAIN TENSOR

Abbreviating the intercept of a_1 vs. $\sin^2\psi$ as I, then at any Φ:

$$\varepsilon_{33} = I\ (\text{of } a_1 \text{ vs. } \sin^2\psi), \tag{13a}$$

$$V(\varepsilon_{33}) = V(\ell_1) + V(I) \tag{13b}$$

$$V(I) = \frac{\Sigma(\sin^2\phi_i - \overline{\sin^2\phi})^2}{N} \cdot \left[\frac{\Sigma(\sin^2\phi_i - \overline{\sin^2\phi})}{\Sigma(\sin^2\phi_i - \overline{\sin^2\phi})^2}\right]^2 \quad V(a_{1\ i})$$

$$= \frac{1}{N}\ \frac{[\Sigma(\sin^2\phi_i - \overline{\sin^2\phi})]^2}{\Sigma(\sin^2\phi_i - \sin^2\phi)^2}\ V(a_{1\ i}) \tag{13c}$$

Now, from Eqs. (3c), at $\Phi = 0°$:

$$_0\ell_1 = \varepsilon_{11} - \varepsilon_{33} = \varepsilon_{11} - I, \tag{14}$$

$$V(\varepsilon_{11}) = 2V(_0\ell_1) + V(I).$$

Similarly, for $\Phi = 90°$:

$$\varepsilon_{22} = {}_{90}\ell_1 + I,$$

$$V(\varepsilon_{22}) = V({}_{90}\ell_1) + V({}_{0}\ell_1) + V(I), \tag{15}$$

and for $\phi = 45°$:

$$\begin{aligned} \varepsilon_{12} &= {}_{45}\ell_1 + \varepsilon_{33} - 0.5\,(\varepsilon_{11} + \varepsilon_{22}) \\ &\quad + {}_{45}\ell_1 - 0.5\,({}_{0}\ell_1 + {}_{90}\ell_1), \end{aligned}$$

$$V(\varepsilon_{12}) = V({}_{45}\ell_1) + 0.25\,[V({}_{0}\ell_1) + V({}_{90}\ell_1)]. \tag{16}$$

From Eqs. (3d):

$$V(\varepsilon_{12}) = V({}_{0}\ell_2), \tag{17}$$

$$V(\varepsilon_{23}) = V({}_{90}\ell_2). \tag{18}$$

THE STRESS TENSOR

We define $Q = S_1/(3S_1 + 1/2S_2)$ (which is $[^{-\nu}/1\text{-}2\nu]$ for an isotropic solid). Then Eq. (4) may be written, for the diagonal stress components, as:

$$\sigma_{ij} = (1/2S_2)^{-1}[(1-Q)\varepsilon_{ii} - Q\varepsilon_{kk} - Q\varepsilon_{jj}]. \tag{19}$$

Here $i = 1,2,3$; $j = 2,3,1$; $k = 3,1,2$.

From Eq. (19):

$$V(\sigma_{ii})^{\frac{1}{2}} = (1/2S_2)^{-1}\,\{(1-Q)^2 V(\varepsilon_{ii}) + Q^2[V(\varepsilon_{kk}) + V(\varepsilon_{jj})]\}^{\frac{1}{2}}. \tag{20}$$

Therefore, with Eqs. (13-15):

$$\begin{aligned} V(\sigma_{11})^{\frac{1}{2}} = (1/2S_2)^{-1}\,\{&(2-4Q + 4Q^2)V({}_{0}\ell_1) + Q^2V({}_{90}\ell_1) \\ &+ (1-2Q + 3Q^2\ V(I)\}^{\frac{1}{2}}, \end{aligned} \tag{21}$$

$$\begin{aligned} V(\sigma_{22})^{\frac{1}{2}} = (1/2S_2)^{-1}\,\{&(1-2Q + 4Q^2)V({}_{0}\ell_1) + (1-2Q + Q^2)V({}_{90}\ell_1) \\ &+ (1-2Q + 3Q^2)V(I)\}^{\frac{1}{2}}, \end{aligned} \tag{22}$$

$$\begin{aligned} V(\sigma_{33})^{\frac{1}{2}} = (1/2S_2)^{-1}\{&(1-2Q + 4Q^2)V({}_{0}\ell_1) + Q^2V({}_{90}\ell_1) \\ &+ (1-2Q + 3Q^2)V(I)\}^{\frac{1}{2}} \end{aligned} \tag{23}$$

Similarly:

$$V(\sigma_{12})^{\frac{1}{2}} = (1/2S_2)^{-1}[V({}_{45}\ell_1) + 0.25\ [V({}_0\ell_1) + V({}_{90}\ell_1)]^{\frac{1}{2}}, \tag{24}$$

$$V(\sigma_{13})^{\frac{1}{2}} = (1/2S_2)^{-1}V({}_0\ell_2)^{\frac{1}{2}}, \tag{25}$$

$$V(\sigma_{23}) = (1-2S_2)^{-1}V({}_{90}\ell_2)^{\frac{1}{2}}. \tag{26}$$

EXAMPLES

To illustrate the typical magnitudes of the errors due to counting statistics, we employed data from Ref. 5, for a ground steel specimen, that is we used the peak positions and the variances in these positions with Eq. (9). [Formulae to calculate this variance for the parabolic fit employed in Ref. 5 are given in Ref. 1; for other types of fits the appropriate equation may be substituted.] The resultant errors are given in Tables I-III. For the first two tables it was assumed that the error in $d_{\phi,\psi}$ was the actual measured value. If there is no preferred orientation, the intensity of the peak changes little with the ψ-tilt. In this case, Tables I and II show the effect of the uncertainty in d_0; reducing this error all the stress components by the same proportion, except σ_{13}, σ_{23}, which remain relatively unaffected, because the role of the error in d_0 is damped by $(d-)^2$ in Eq. (12).

If there is preferred orientation, the peak intensity can vary greatly with ψ and there will be large variances contributing to $V(\ell_1)$ from weak peaks. This was minimized in the following way. The average variance, σ_i, in the 2θ peak position for $+\psi$ and $-\psi$ was obtained and the weighting factor c_i was formed:

$$c_i = (1/\sigma_i^2)\ /\ \sum_i (1/\sigma_i^2) \tag{27}$$

The Eqs. 11 and 12 were then altered to multiply $V_i(2\theta^+)$, $V_i(2\theta^-)$ terms by this weighting for Table III. There is only a small difference (between Tables II and III) because of the lack of texture in the specimen; the peak intensity changed only by about 8 pct with ψ. With more severe preferred orientation the effect will be larger.

CONCLUDING REMARKS

There are now adequate equations for calculating errors in stress

TABLE II: STRESS TENSOR AND STANDARD DEVIATIONS WHEN $V(d_0)^{1/2} = 0.00004$ Å *

DATA SET 1

539.74	(48.24)	-24.03	(24.50)	-39.15	(4.58)
		552.16	(47.26)	2.30	(3.56)
				80.41	(38.96)

DATA SET 2

520.60	(40.52)	-4.03	(19.95)	-34.17	(3.21)
		555.19	(39.73)	0.11	(2.69)
				82.20	(32.75)

DATA SET 3

535.03	(47.81)	-20.14	(24.35)	-40.19	(5.72)
		555.98	(46.81)	-0.98	(4.56)
				86.66	(38.84)

DATA SET 4

538.53	(42.84)	-30.63	(21.10)	-38.03	(3.83)
		565.37	(42.51)	0.76	(3.89)
				88.18	(34.67)

*values given in MPa

TABLE III: WEIGHTED STRESS TENSOR AND STANDARD DEVIATIONS*

DATA SET 1

536.24	(48.56)	-24.62	(24.56)	-38.33	(4.59)
		554.65	(47.60)	2.90	(3.65)
				80.68	(39.22)

DATA SET 2

520.29	(41.84)	-6.04	(20.11)	-34.82	(3.55)
		560.22	(40.60)	1.56	(2.73)
				85.29	(33.76)

DATA SET 3

532.56	(48.15)	-7.90	(24.93)	-39.66	(5.81)
		549.83	(47.16)	-2.81	(4.57)
				82.21	(39.16)

DATA SET 4

539.23	(42.88)	-31.22	(21.23)	-38.28	(3.85)
		565.17	(42.65)	-0.59	(3.94)
				88.98	(34.68)

* $V(d_0)^{1/2} = 0.00004$ Å; values given in MPa

measurements due to instrumental effects, counting statistics and in the x-ray elastic constants. We would like to conclude this paper with a plea to the community making stress measurements via diffraction to regularly report these errors with their data. It is all too common for investigators to repeat a measurement (of stress or an elastic constant) once and to use the difference as an error estimate. Another practice is to dust a stress-free powder on the specimen surface and to use a (single) measurement of the stresses measured with this powder as an error estimate. Finally, some report an error in a slope vs. $\sin^2\psi$ obtained by least-squares, but ignore the uncertainty in each point in this plot in estimating errors. None of these procedures is particularly satisfying in a statistical sense. Of course, if time permits, the average of, say, ten repetitions of a measurement is the best of all error estimates. If this cannot be done, error estimates from the available equations are far more satisfactory than the currently all - too common procedures.

ACKNOWLEDGEMENTS

This research was supported by ONR under contract No. N00014-80-C116. We thank Dr. I. C. Noyan for his advice.

REFERENCES

1) M. R. James and J. B. Cohen, Study of the Precision of X-ray Stress Analysis, Adv. X-ray Analysis, 20:291(1977).
2) R. H. Marion, "X-ray Stress Analysis in Plastically Deformed Metals", Ph.D. Thesis, Northwestern University (1973).
3) S. Taira, T. Abe and T. Ehiro, X-ray Study of Surface Residual Stress Produced in Fatigue Process of Annealed Metals, Bull J.S.M.E., 12:53, 947(1969).
4) K. Perry, I. C. Noyan, P. J. Rudnik and J. B. Cohen, "The Measurement of Elastic Constants for the Determination of Stresses by X-rays, Adv. X-ray Analysis, 27: 159(1984).
5) H. Dolle and J. B. Cohen, Residual Stresses in Ground Steels, Met. Trans., 11A:831(1980).
6) I. C. Noyan, Equilibrium Conditions for the Average Stress Measured by X-rays, Met. Trans., 14A:1907(1983).
7) A. D. Krawitz, J. E. Brune and M. J. Schmank, Measurement of Stress in the Interior or of Solids with Neutrons in: "Residual Stresses and Stress Relaxation", E. Kula and V. Weiss eds., Plenum Press New York (1982).
8) I. C. Noyan, Determination of the Unstressed Lattice Parameter, "a_0" for (Triaxial) Residual Stress Determined by X-rays, Adv. X-ray Analysis, 28: (1985).
9) O. Davies and P. Goldsmith, Statistical Methods in Research and Production, Hafner Publ. Co., New York (1952).

AD-A158219

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) J. B. Cohen Northwestern University Evanston, IL 60201	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP

3. REPORT TITLE

ERRORS DUE TO COUNTING STATISTICS IN THE TRIAXIAL STRAIN (STRESS) TENSOR DETERMINED BY DIFFRACTION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

TECHNICAL REPORT # 18

5. AUTHOR(S) (First name, middle initial, last name)

P. Rudnik
Jerome B. Cohen

6. REPORT DATE July 1, 1985	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. N00014-80-C-116 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 18 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Distribution of document is unlimited

11. SUPPLEMENTARY NOTES In this paper the	12. SPONSORING MILITARY ACTIVITY Metallurgy Branch Office of Naval Research

13. ABSTRACT

The errors are derived for the diffraction measurement of the three dimensional stress and strain tensor due to counting statistics.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Stresses Residual stresses Errors in residual stresses Counting statistical errors in stresses						